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Proposed VOC Sampling Network for a Complex
Urban/Industrial Area: Fairfax Sampling Proposal

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A PROPOSED VOC SAMPLING NETWORK FOR A
COMPLEX URBAN/INDUSTRIAL AREA:
FAIRFAX SAMPLING PROPOSAL

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EXECUTIVE SUMMARY

As part of an ongoing University of Kansas and U. S. EPA, Region VII, volatile organic compounds (VOC) ambient air sampling network study using whole-air samplers, a NNEPS Fellowship sponsored project was conducted to develop a sampling scheme for the Fairfax Industrial District located in Kansas City, Kansas.

The Fairfax Industrial District is a complex urban/industrial area possessing a wide variety of VOC sources. The complexity of the site (multiple VOC sources) makes individual source monitoring and discrimination difficult with existing sampling networks. However, the addition of a sequential, multi-collection sampler will improve existing sampling networks such that individual source contributions within a multiple VOC source environment can be identified and quantified.

The overall objective of this study will be the development of a sampling protocol and design that is simple to operate and will allow a regulatory agency to monitor a given urban/industrial source with a reasonable degree of confidence. This objective will be developed using a four step procedure consisting of: a site characterization to collect and organize VOC emission and background information, VOC and micrometeorological data collection using the sequential, multi-collector method, analysis and integration of resulting data using gas chromatography/mass spectrometry and back trajectory analysis, and an interpretation of resulting data using a discriminant matching technique.

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1. INTRODUCTION

The use of evacuated stainless steel samplers (ESSS) for monitoring ambient levels of volatile organic compounds (VOC) has been shown to be a viable and effective sampling method. The University of Kansas, in cooperation with Region VII/ U.S. EPA, is proposing the use of ESSS in an urban industrial district. The ultimate goal of this study is the development of a portable sampling station which would allow a state agency or other enforcement group to monitor a given source with a reasonable degree of confidence.

1.A Background and Scope

The University of Kansas and Region VII have been active in the development of whole air sampling techniques. During the period 1985 - 1989, a viable sampling network and protocol were developed for an isolated/elevated/rural VOC source (Lane, et al, 1989). In general, this network consisted of a triangular-shaped sampling area demarcated by radials separated by 30° to 45°; the vertex was centered on the emitting source. ESSS were placed on each of the radials generally at two downwind distances. In addition a single upwind background sampler was also included (Figure 1).

Sample collection runs were conducted over a period of 20 to 30 minutes under similar synoptic meteorological conditions. Analyses of the samplers were done using cryogenic preconcentration gas chromatography (GC). Results from these

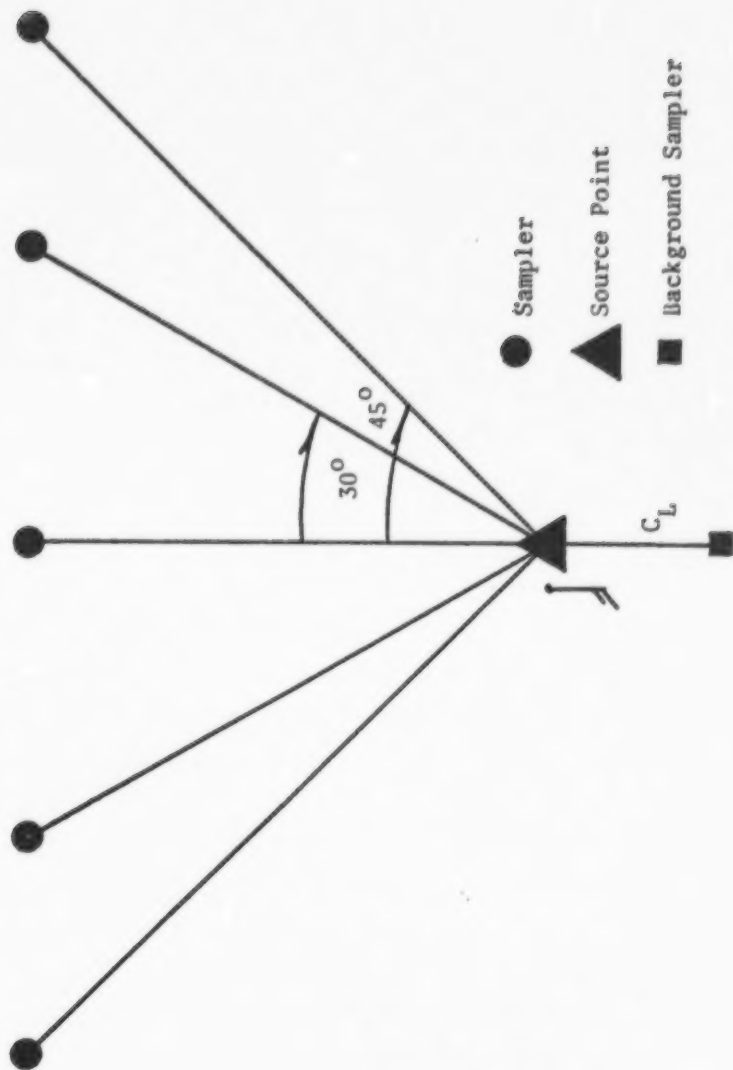


Figure 1

tests showed this network to be flexible and allowed single source identification with a high degree of confidence (Lane, et al, 1989).

1.B Objective

A logical extension of this research would be the development of an ESSS sampling network for use in an urban/industrial area. In contrast to a rural setting, an urban/industrial area contains multiple VOC emission sources within a substantially different micrometeorological environment. The primary objective of this study will be the design and evaluation of a suitable sampling network for such an environment which will be based, in part, on modifications to the single source network and protocol. These modifications will be tested in a multi-source complex urban/industrial setting.

1.C Research Design

The overall research design consists of three major procedural steps; site characterization, sampling, and data analysis (Table 1). Each successive step will be dependent on completion of the preceding.

A site characterization will be conducted for the industrial district. Physical characteristics, emission information, and typical meteorological conditions will be gathered and organized. This information will lay the framework in selecting target VOC compounds and developing network configurations applicable to the district.

The sampling scheme proposed for this study reflects the

<u>SITE CHARACTERIZATION</u>	<u>SAMPLING</u>	<u>ANALYSIS</u>
Site Geometry		Chemical Analysis
-- Maps		Meteorological analysis
-- Air photos	-- Synoptic forecast -- On-site investigation	Data integration
Source Inventory	Network Development	
-- State/EPA listing	-- Primary sampler	
-- City listing	-- Modifications	
-- Chemical discrimination		
Meteorology	Network Deployment	
-- On-site	-- Sampling	
-- Synoptic	-- Repetitions needed	

Table 1

complex nature of the district. Selection and implementation of a network will be highly dependent on the local meteorology and geographical constraints present in the study area. These controlling factors may result in a network deployment that is different from sampling day to sampling day.

Analysis of collected chemical and meteorological data will involve a three phase procedure. Chemical data will be analyzed using GC/MS. GC/MS results will be integrated with collected meteorological data using back trajectory analysis. This comprehensive data set will be used to statistically match a particular measured VOC compound to the most probable source.

The preceding research design will be accomplished using modifications to formalized and tested steps (6 in number) developed in previous work (Lane, et. al, 1989):

- 1) A thorough understanding of the regional geographical layout, including boundaries of the area under study, building heights and orientation, and the accessibility of suitable sites for setting up equipment;
- 2) The development of a detailed regional VOC source inventory for the area based on current state and local pollution data;
- 3) The development of probable VOC emission profiles and finger print emissions based on industry type;
- 4) The selection of synoptic meteorological conditions which will offer the best sampling environment;
- 5) The modification of the sampling network to permit

meaningful sampling results;

6) The selection of acceptable sampling days based on forecasted synoptic scale meteorology;

7) The determination of the location and orientation of the sampling network based on sampling day synoptic and micrometeorological conditions;

8) An on-site micrometeorological investigation to access the character of the wind field for the area on a sampling day;

9) Collection of ambient air samples using ESSS;

10) The analysis of ESSS contents using cryogenic preconcentration GC and mass spectrometry;

11) The integration of ESSS results with probable VOC profiles and collected meteorological data to form a comprehensive data base;

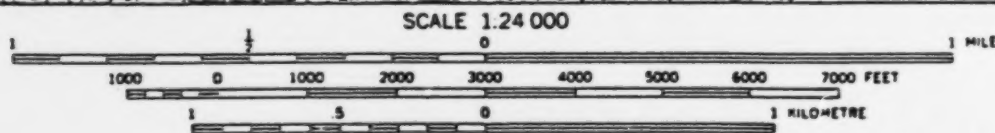
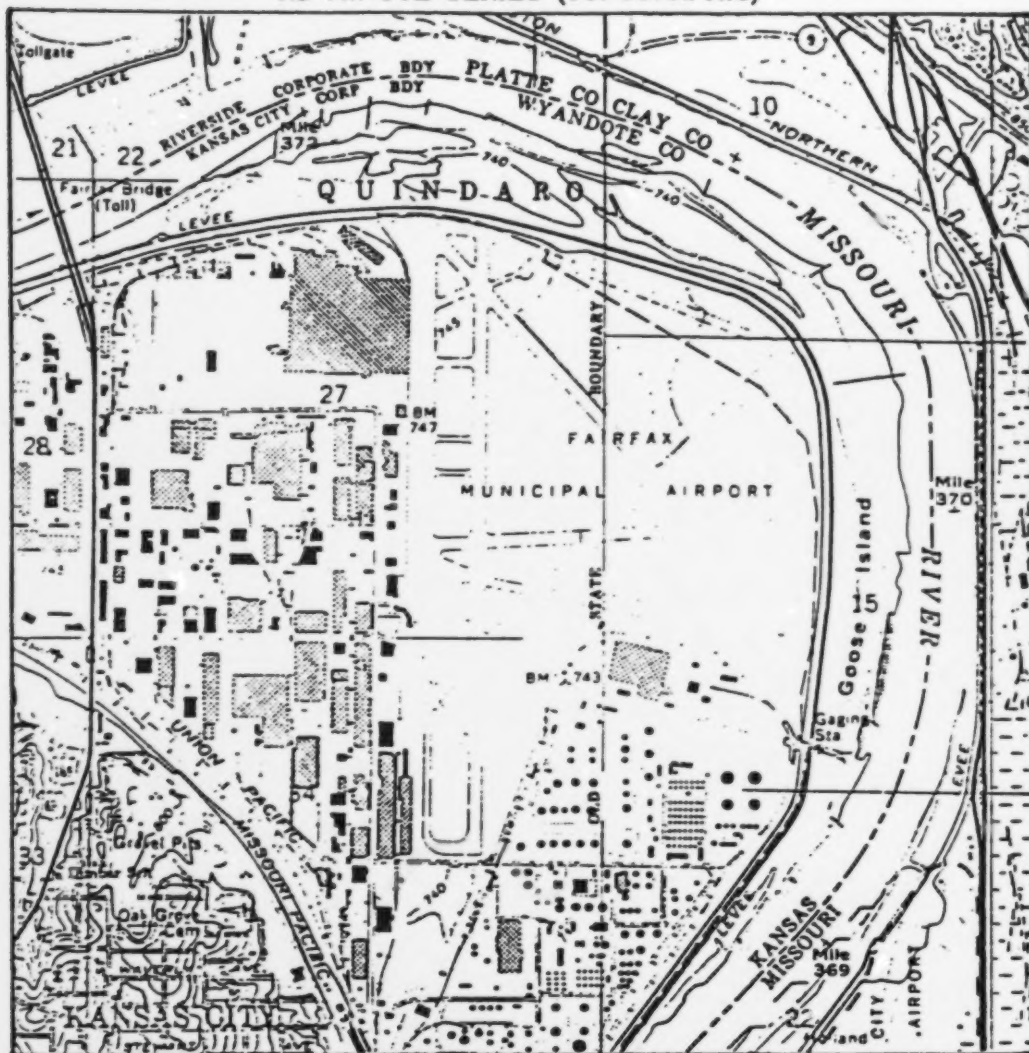
12) The location of probable VOC emission sources based on the integrated ESSS data base using a discriminant analysis technique.

2. STUDY AREA AND SITE CHARACTERIZATION

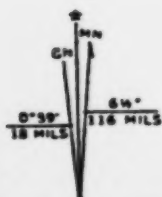
The proposed area of study for this project will be the Fairfax Industrial District located in the extreme eastern portion of Wyandotte County, Kansas (Figure 2). The Fairfax district possesses a wide variety of VOC sources produced by manufacturing, chemical production, and transportation activities making it a suitable study area for the development of an urban sampling system.

Figure 2

NORTH KANSAS CITY QUADRANGLE
MISSOURI-KANSAS
7.5 MINUTE SERIES (TOPOGRAPHIC)



CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929



NORTH KANSAS CITY, MO.-KANS
N3907.5 - W9430/7.5

1964
PHOTOREVISED 1970 AND 1975
AMS 7062 II NE-SERIES V879

UTM GRID AND 1975 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

A detailed site investigation and characterization are necessary in order to efficiently design and evaluate a sampling network. These steps will consist of a site geometry study, assemblage of all available source locations and inventories, and characterization of the on-site and synoptic meteorology.

2.A Site Geometry

The layout and implementation of a sampling network is dependent on the site geometry (topography, building layout, and transportation network) and associated geographical restrictions. Topographical and city maps in addition to air photography will be used to construct the site geometry.

2.A.1 Topographic maps

Information consisting of the local relief and geography of the study area will be ascertained from USGS 7.5', 1:24000, 10 foot contour interval topographic maps. These maps show locations of transportation systems, land use and natural features of the area. Maps of the entire Fairfax region will be obtained from the Kansas Geological Survey.

2.A.2 City maps

Topographic maps, at a scale of 1:24000, generally lack the resolution necessary to accurately locate individual VOC source emission locations. City maps are usually at a much larger scale (1:12000) and normally contain street names and industrial locations, which make accurate source location possible. Maps for the City of Kansas City, Kansas will be obtained from the Wyandotte County Planning Office.

2.A.3 Air photos

It is possible that the survey dates of some of topographic and city maps may predate recent developments in the district. A complete and current air photo assemblage will be obtained for up-dating these maps. These photos will also be useful in assessing potential network deployment areas.

2.B Assemblage of all source inventories

A detailed assemblage of all source inventories is critical if efficient network design and deployment is to be accomplished. Such information will be obtained from the State of Kansas VOC emission inventory and the Wyandotte County pollution inventory; the two will allow a complete inventory of the district to be constructed. A chemical profile inventory, a listing of probable VOC emissions from a given source, will also be generated based on the source inventory information and a profile-generating computer program.

2.B.1 State/EPA inventory listing

A complete and up-to-date (1989) emission inventory will be obtained from the Kansas Department of Health and Environment. This inventory consists of a detailed listing of all VOC emitting sources that lie in the Fairfax district, in addition to specific source characteristics of each (plant name, UTM location, and emission rate/characteristics)(sample listing). A supplementary inventory package (EPA Speciate) will also be obtained. This system allows a user to specify general industry types (Source Classification Code (SCC)) for which a specific VOC listing or

profile is generated, reflecting that industry's VOC emission.

2.B.2 Local city inventory

Even though the data contained in the State of Kansas source VOC inventory are considered to be detailed and accurate, reporting methods such as source grouping into one location are not uncommon. Because of this, the Wyandotte County Health Department (Air Pollution Division) will be contacted. Such a local agency is well suited to examine the State data and make additions and adjustments to the original data based upon their more detailed knowledge of the district.

2.B.3 Chemical Discrimination

The supplementary EPA software package Speciate provides information about the chemical nature of emissions from various industry types. The resulting emission profile is presented in the following way: each component of the emission is listed by chemical name, along with the percentage (by weight) of that component in the emission. In many cases, the chemical name used is not compound specific. For example, rather than n-hexane, one of the following terms may be used: hexane, isomer of hexane, or C-6 paraffin.

In order to facilitate comparisons among the various emission profiles, or between ambient air profiles and emission profiles, the components will be sorted into chemical groups, each of which will be further broken down into subgroups. In some cases, a subgroup may consist of a single common and/or important compound, such as benzene or toluene. In other cases,

the subgroup may consist of an entire class of compounds, such as organic acids. At the completion of this sorting, each emission profile will consist of identical groups, with a percentage associated with each group and subgroup, reflecting its contribution to the emission. This same sorting procedure can be performed on results of ambient air sample analyses. The profiles could then be subjected to quantitative tests of similarity, e.g., between two emission profiles, or between an emission profile and an ambient air profile.

2.C Characterization of the on-site and synoptic meteorology

Sampling of ambient level VOC concentrations is known to be highly dependent on the local micrometeorology and on the synoptic meteorological setting (Thomas, 1988). Generally conditions of consistent wind flow are characteristic of neutral to stable conditions and typically occur during times of post cold-frontal air flow. Such conditions allow accurate network orientation establishment, and ESSS deployment. In order to minimize the possibility of sampling under non-ideal flow conditions, on-site and synoptic meteorological conditions affecting the Fairfax district will be conducted. This will allow the optimum time of day and year to be predicted for the deployment of a sampling network.

2.C.1 On-site Meteorology

The on-site meteorological history of the district will be assembled from surface data taken from the Kansas City, Missouri

Downtown Municipal airport. Data summaries (wind speed and direction, mixing heights, and temperature/humidity) are available from the National Weather Service.

Wind data will be organized into monthly wind roses allowing a graphical depiction of the climatologically-prevailing wind direction. These directions, in conjunction with the morning and afternoon mixing heights will allow times of probable favorable sampling conditions to be determined on a climatological basis.

2.C.2 Synoptic Meteorology

The synoptic meteorological setting of the region will be characterized using surface, 500 mb and 850 mb weather maps available from the National Climatic Data Center. These maps will show the frequency and time of year that specific, favorable synoptic conditions are most prevalent.

3. SAMPLING

The selection, implementation, and evaluation of a sampling network will be dependent on the local meteorological environment, geographical features, and the degree of selectivity required in the study. Failure to address these features will lead to results which are inconsistent and provide little useful information.

3.A Importance and protocol of a meteorological forecast

A thorough understanding of the synoptic and on-site meteorological conditions affecting an area are the most

important first steps in selecting and implementing a sampling network. Different conditions (principally wind direction) will likely require different network configurations to be used. Since network deployment does involve a certain degree of preparation, meteorological conditions present on the proposed sampling day must be forecasted.

3.A.1 Synoptic Forecast

The climatology of the wind field will be used as a guide in selecting possible sampling days. This will be followed by a synoptic forecast 48 and 24 hours in advance of the sampling day. Eight hundred and fifty millibar (850 mb) and 500 mb National Weather Service meteorological charts will be used to predict winds over the district. These charts are readily available at the University of Kansas Weather Service and have been used for this purpose in the past.

3.A.2 Initial meteorological investigation

An initial on-site meteorological investigation is critical in setting up a given network centerline. Generally this investigation should include a 30 to 60 minute evaluation of the wind conditions prior to network deployment. Critical items are the mean wind speed and direction and any significant directional deviations. If deviations or backing (wind direction consistently decreasing in direction, an indication of decreasing instability) conditions are present, deployment of the network will be delayed.

Such meteorological assessments will not involve data or

equipment that are complex. The location of the meteorological monitoring station will be near the anticipated primary sampling location. Principle variables measured will be the wind speed and direction; temperature and humidity measurements, although not necessary for network deployment, are useful in specific types of modeling and will be collected.

The equipment used in this study consists of a Campbell Scientific/R. M. Young self-contained instrument mast, which measures the one minute averages of the wind components, temperature, and humidity. Magnetic tape storage is also a feature of the system.

3.B Deployment of an urban sampling network

Ambient air sampling in an urban environment constitutes a much more complex problem than in a rural setting due to numerous sources which are generally present in an urban area, the roll that sampling network deployment is constrained by buildings and property lines, and the effect of synoptic and on-site meteorological conditions. In addition, an assessment of the proposed sampling outcome must be made; i.e., is the network to be selective in source discrimination or sensitive to the overall ambient environment.

A possible network choice would include one which has been proven to be viable, cost effective, and offers flexibility in relation to the specific urban/industrial environment present. A sampling design that meets these basic requirements is the University of Kansas/ Region VII rural sampling network.

Specifically this network possesses the following features:

- 1) The system has been shown to produce accurate and repeatable results.
- 2) The system is flexible with regard to both geography and meteorology.
- 3) In general, the system is easy to set-up and operate with a minimal of demands on sampling equipment and personnel.

3.B.1 Choice of the network

The features of the rural sampling network indicate that this design offers a good basis for the development of an urban sampling network. Several modifications, reflecting the anticipated conditions in the district, are being considered for testing and evaluation and include: the addition of a primary sampler, a background curtain, addition of signature samplers, and network simplification.

3.B.1.a Addition of a primary sampler

The rural network was designed for single isolated source situation in comparatively simple terrain. In general, the network must be modified to allow identification of multiple sources present in a complex urban/industrial environment. A modification, which allows for multiple source discrimination while maintaining a known degree of confidence for plume location, is the addition of a primary sampler to the basic network (Figure 3). The primary sampler is composed of several rapidly opened, short duration, sequential samplers (up to 24 in series). Each sampling period is coordinated with concurrent

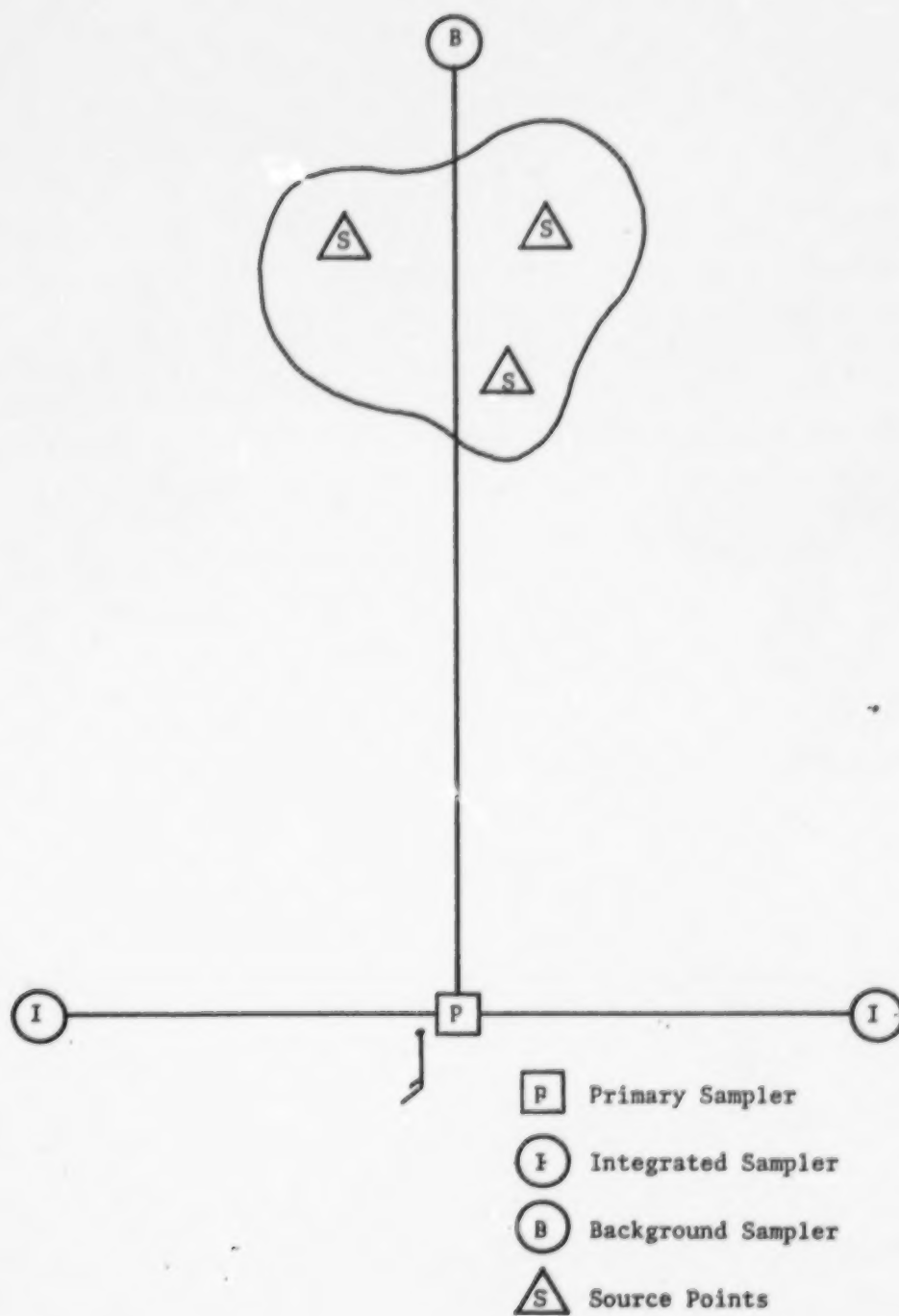


Figure 3

wind direction and velocity data by using back trajectory analysis (BTA). This allows each sampler's chemical contents or profile to be back tracked over the study area, which allows a direct comparison between each profile's trajectory and the sources it passed over. Additional integrated wing and background sampler data collected over the course of the test allow plume confidence limits to be drawn through direct comparison with the primary samples.

3.B.1.b The use of a background curtain

A common situation in an urban/industrial setting, which can compound an ambient concentration study, is one in which upwind sources are present. A possible design that would lessen the influence of these sources includes the addition of a curtain of three to four integrated background samplers to the basic network (Figure 4). Chemical analysis of the curtain samplers makes possible a tagging technique which allows the upwind VOC contribution to be subtracted from that of the primary samplers. This in turn enhances the identification and discrimination of the study area sources.

3.B.1.c The use of signature samplers

A potentially troublesome sampling scenario includes a situation in which unknown or new sources are present in the study area due to deficiencies in state or local source inventories. A network design that would help to overcome this problem involves the use of signature samplers (Figure 5). These samplers would be placed directly in the area of interest and



Figure 4

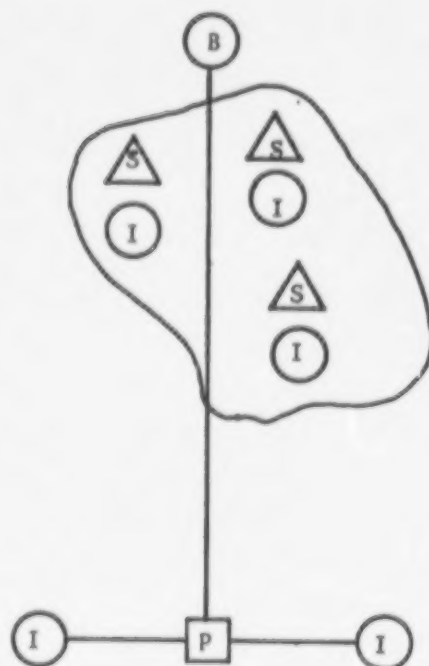


Figure 5



Figure 6

- P Primary Sampler
- I Integrated Sampler
- B Background Sampler
- △ S Source Points

operated in an integrated fashion. Analysis of the samplers would allow unknown and new sources to be located and the character of their emission determined. This design would also be useful in confirming the emissions (and profiles) of existing sources for which inventory information has been gathered. Both approaches would help to enhance the discrimination process.

3.B.1.d Simplified network

In certain circumstances a source may emit a specific and unique compound found nowhere else in the district. In this situation, a simplified network consisting of single integrated primary and background samplers would be useful (Figure 6). Under extreme meteorological conditions (such as large directional swings), integrated wing samplers may also be used.

3.B.2 Selection of the study area and network

Once the wind field over the district has been forecasted, a study area within the district will be selected based on the wind flow and the geographical lay-out of the district (i.e., accessibility for network deployment). This study area will then define the type of network modification needed to reasonably measure VOC concentration levels for that specific area under the forecasted meteorological conditions.

3.C Network deployment

After an assessment of local wind characteristics is computed, the appropriate network will be deployed. The first step in this procedure will involve discussion with each team member so that sampler locations will be positioned as close to

the network centerline as possible. Each member will then travel as quickly as possible to that location and set up their appropriate sampler. Since team members will likely be separated by substantial distances, set-up activities will be conducted from the primary sampling location with 2-way radios.

3.D Sampling

After a last minute check of the wind direction, a signal from the team leader will initiate the test. All team members will then open their samplers. As indicated in previous sections, the primary sampler will consist of a timed series of individual, short duration samples. Concurrent collection of meteorological and sampler data will occur to maximize integration of chemical and meteorological data. The test will be terminated after all sequential samplers have been operated, at which time the team leader will signal to close all remaining samplers.

3.E Repetitions of the primary sampler and length of a test

Since the primary emphasis of this study will be the identification of multiple sources, the number of individual samples taken by the primary sampler will be critical. In order to obtain a reasonable degree of confidence, at least 14 samplers should be operated in rapid succession. The length of each opening will depend on the degree of selectivity sought in the test and the nature of the wind field. The total length of the test will then be the total sum of the primary samplers.

4. ANALYSIS

4.A Data Analysis

Analysis of collected data will be performed in three phases: chemical analysis with GC/MS, meteorological analysis using BTA, and source location using discriminant function analysis.

4.A.1 Chemical Analysis

After all sampling is complete, each ESSS will be analyzed using cryogenic preconcentration gas chromatography/mass spectrometry (GC/MS). This combination allows more information to be extracted from samples than with GC alone.

4.A.2 Meteorological Analysis

BTA will be applied to each test using a time interval of one minute. BTA consists of back tracing an air parcel from the sampling site (meteorological station) over the study area using the interval wind speed and direction. Each trajectory then represents the path, or envelope, an air parcel traversed in moving over the study area.

4.A.3 Data integration and Discriminant function analysis

In order to facilitate discriminant function analysis, the chemical and BTA results must be integrated into a common comprehensive data base. This process will be accomplished in the following manner:

- 1) Each interval of primary sampler chemical data will be organized into profiles in a similar fashion to that of the

inventory discrimination;

2) The profiles will next be matched with their corresponding trajectory;

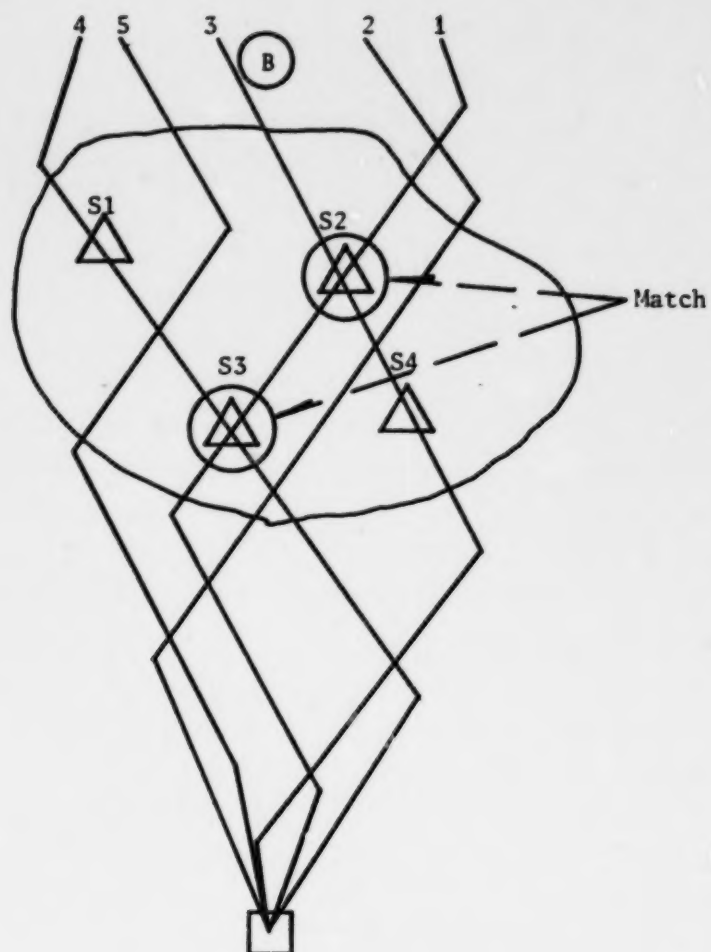
3) From the BTA, a probable chemical profile will be compiled for each trajectory based on the traversed path of that trajectory and the sources passed over (inventory profile);

4) The sampler derived profiles and the probable profiles will then be compared using discriminant function analysis.

Results of this analysis will define the similarity between the chemical profiles (measured) and the BTA/inventory profiles (predicted) which in turn will allow confidence limits to be set for source identification.

5. INTERPRETATION

Since the ultimate goal of interpretation is to identify and locate sources contained in a complex, multiple source area, results of the discriminant analysis and the BTA also will be compared graphically. An example of this technique is illustrated on (Figure 7). In this example, the study area contains four discrete sources. A total of five trajectories passed over the area of which three (trajectories 1, 3, and 4) passed over sources. An examination of the chemical profiles (checked by discriminant analysis) indicate that specific profiles possess similarities in their chemical make-up. These similarities, or matches, correspond to measurements of the same source. The point at which each profile's trajectory intersects locates that specific source. If many trajectories pass over the



Chemical Profiles

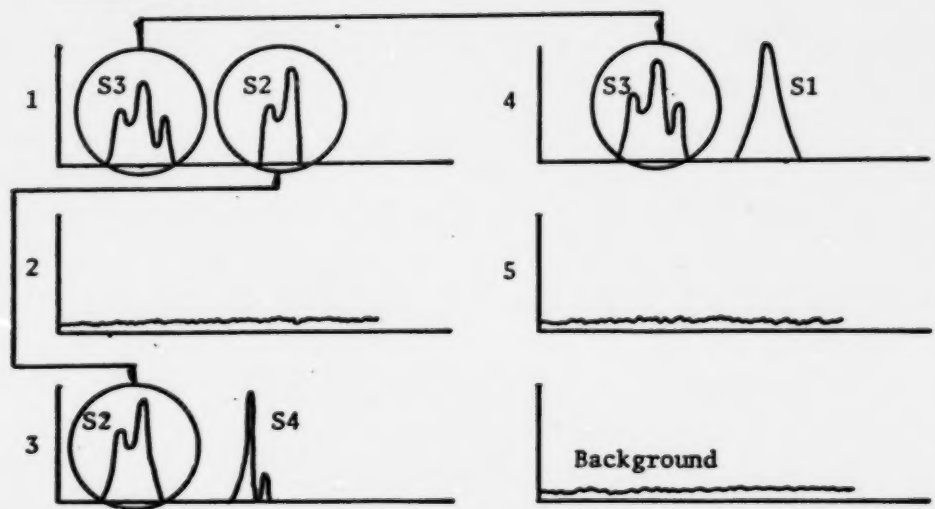


Figure 7

area, subsequent analysis allows location of all sources under study.

6. SUMMARY

A sampling plan to determine ambient level VOC concentration levels in the Fairfax Industrial District has been outlined in this paper. The basic sampling network will be an extension of an established network design and protocol already developed and tested; its on-site deployment and application and will be dependent on geographical and meteorological constraints present in the district. One modification to the extant network design will consist of the addition of a primary sampler, which will allow multiple VOC sources, i.e., those common to the urban/industrial setting, to be measured and quantified.

Ambient air monitoring and assessment in an urban/industrial setting will involve a four step process consisting of: study area and site characterization, VOC and micrometeorological data collection, analysis and integration of resulting data, and an interpretation of results.

The site geometry, VOC source inventory, and meteorological environment will be characterized for the Fairfax District, thus allowing efficient design and evaluation of the sampling project to be performed. Geographical and land usage information will be obtained from USGS and city maps. The VOC source inventory will be developed using the State of Kansas VOC emission inventory and information from the Wyandotte County Health Department. The

synoptic and on-site meteorological character of the district will be developed using National Weather Service maps and surface data.

Sampling in the Fairfax District will consist of four elements: a meteorological evaluation of winds, choice of appropriate network configurations, network deployment, and sampling.

Previous studies have shown the synoptic and on-site meteorology to be important factors in selecting and implementing a sampling network. A synoptic forecast and subsequent on-site meteorological assessment of the wind field will be performed prior to sampling. A thorough understanding of the wind field will allow accurate and efficient network deployment.

The selection of the appropriate network configuration will be a function of the specific area under study and the meteorological conditions present on the sampling day. The usage of the primary sampler network configuration permits specific configurations to be constructed for differing geographical and meteorological settings.

Network deployment and sampling operation will be conducted by a team of experienced individuals. Each test will involve the collection of at least 14 air samples and concurrent meteorological data.

Analysis and integration of the resulting chemical and meteorological data is a two phase process: chemical data will be analyzed using preconcentrated GC/MS; meteorological data

will be used to construct a back trajectory analysis (BTA). Resulting chemical and BTA data will then be integrated into a comprehensive data base.

Interpretation of the integrated data will be enhanced using a discriminant matching technique. Measured VOC concentrations will be matched with their corresponding source locations using a graphical technique.

7. REFERENCES

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